Hydrogen from Green Surplus Energy in Isolated Areas for Sea and Land-based Transport (Faroelyzer)

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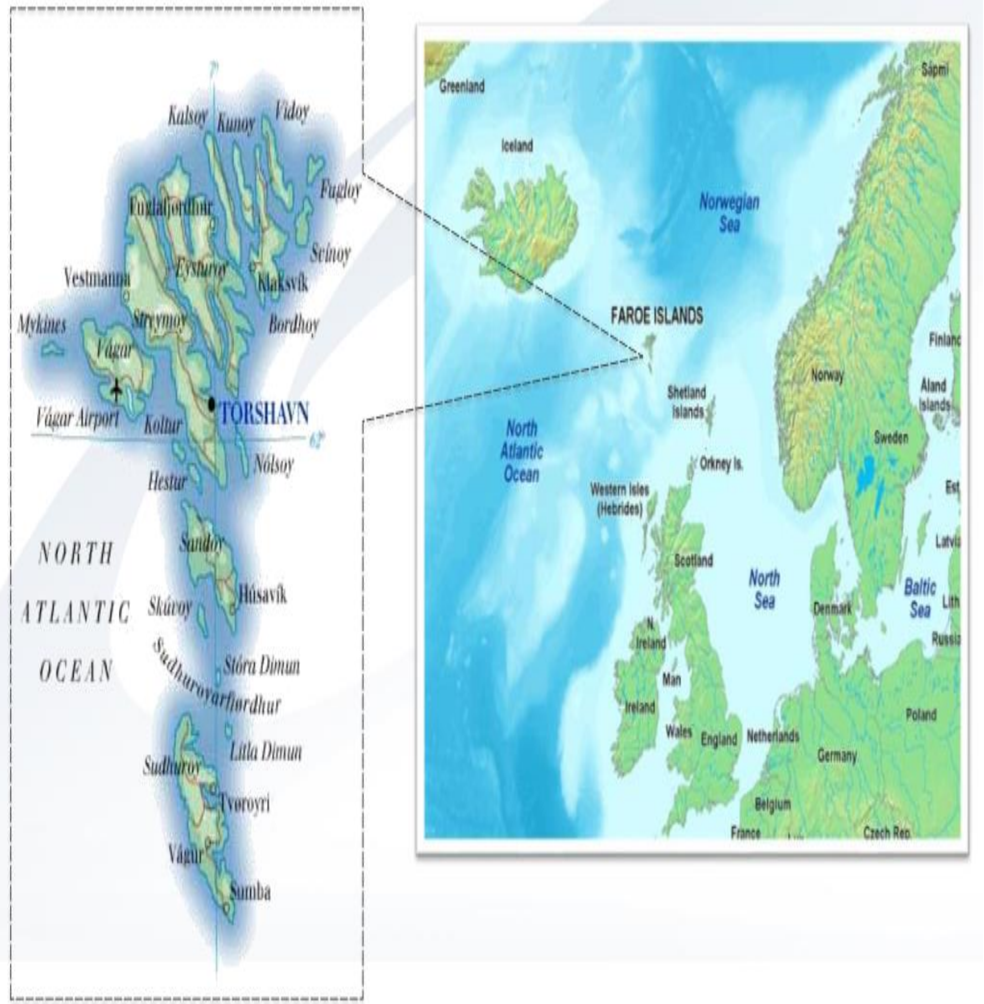
Agenda

- Background
- Faroelyzer introduction
- Interim findings
- Results summary and next step

Faroe Islands' energy transition: background

General data:

- 18 islands (17 are populated)
- 51,000 inhabitants
- Area of 1,399km^2
- Main export: Fish and fish products
- "Micro isolated system" in EU terms (< 500GWh @ 1996)



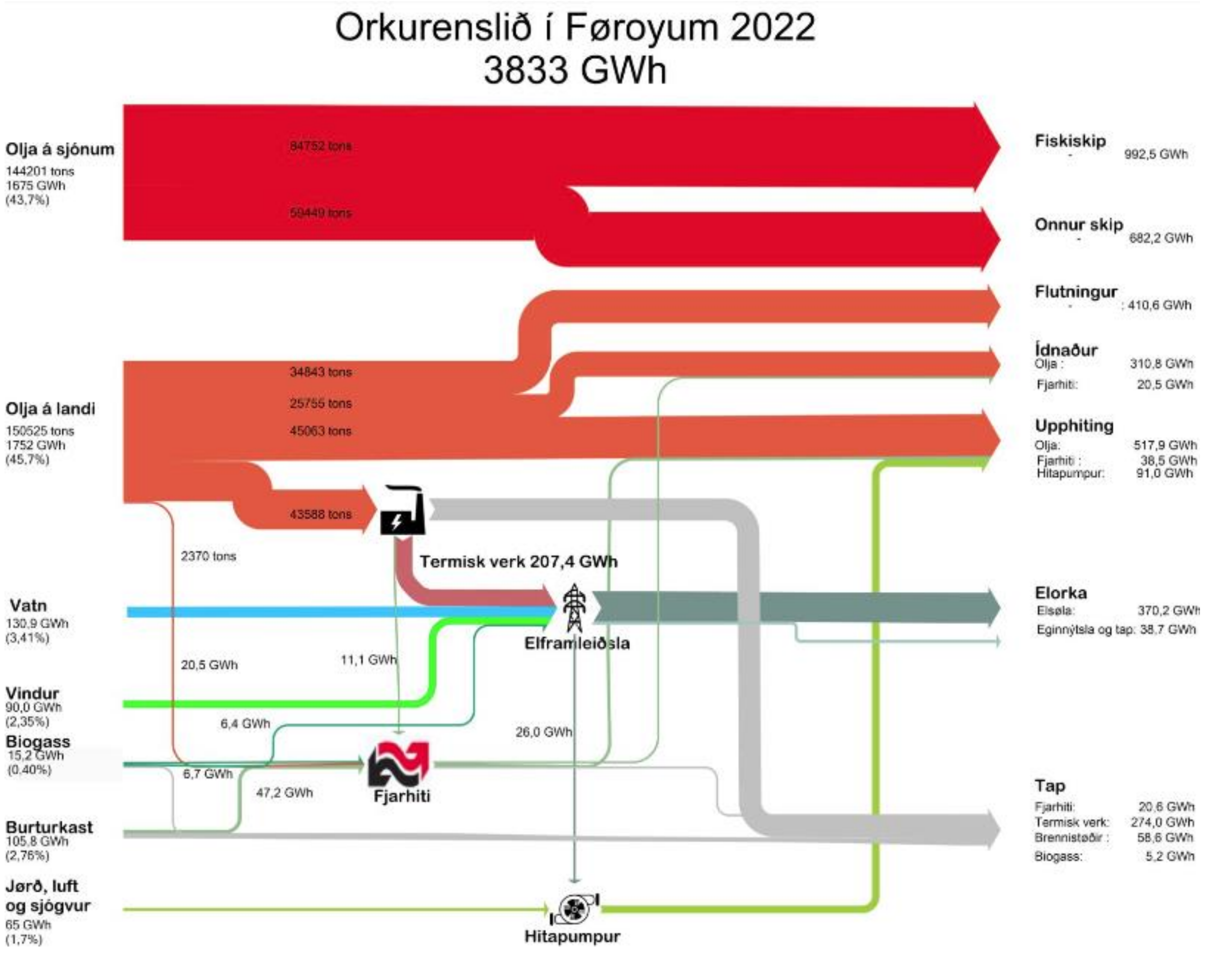
Faroe Islands’ energy transition: status

Electricity

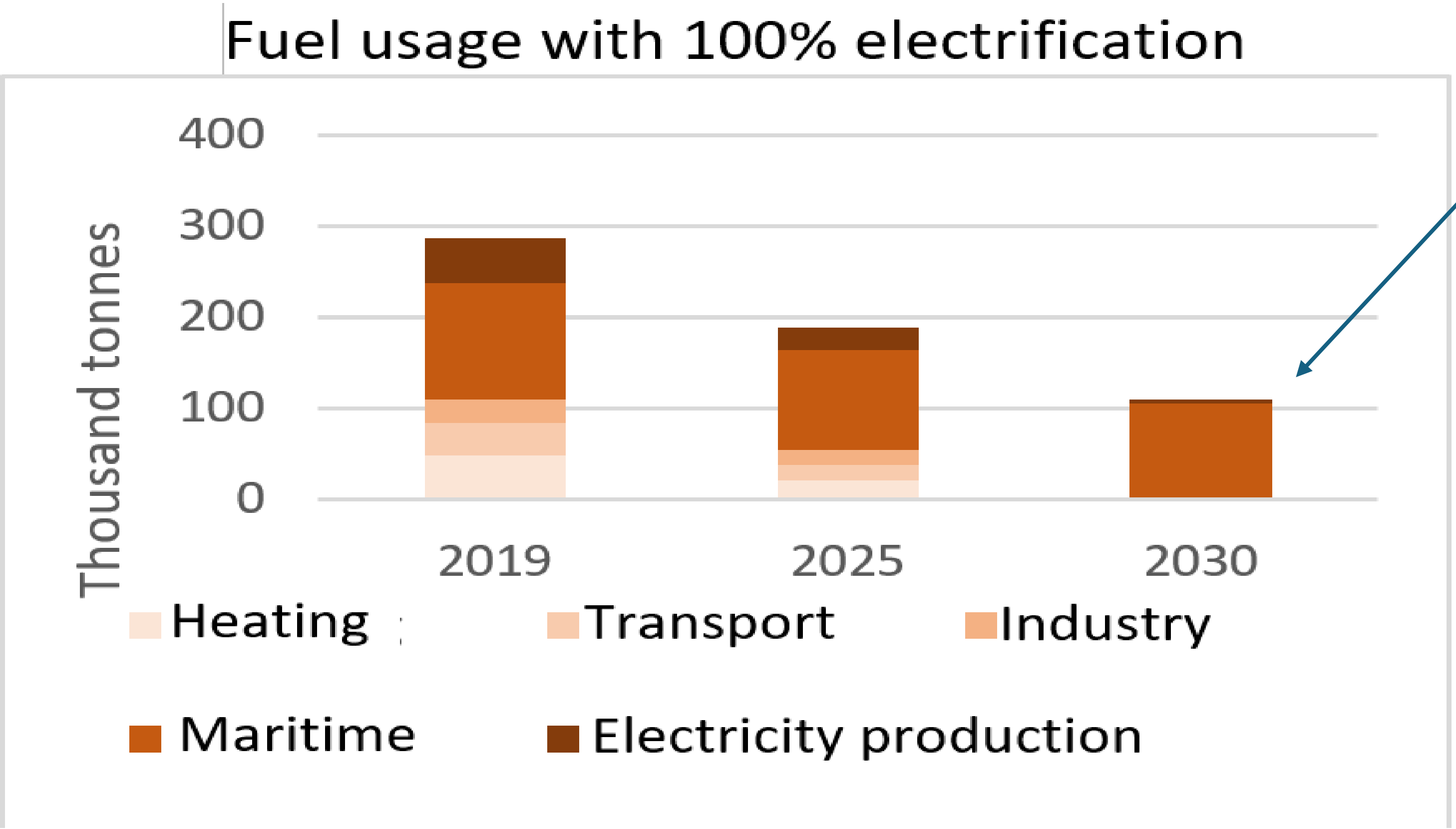
- Just over 50% renewable electricity in 2022
- Aim for 100% renewable electricity in 2030

Total energy consumption

- However, electricity accounts for only 11% of total energy consumption of the Faroe Islands
- Meanwhile, 54% of energy consumption comes from sea and land transport
    - 11% land based
    - 43% sea based



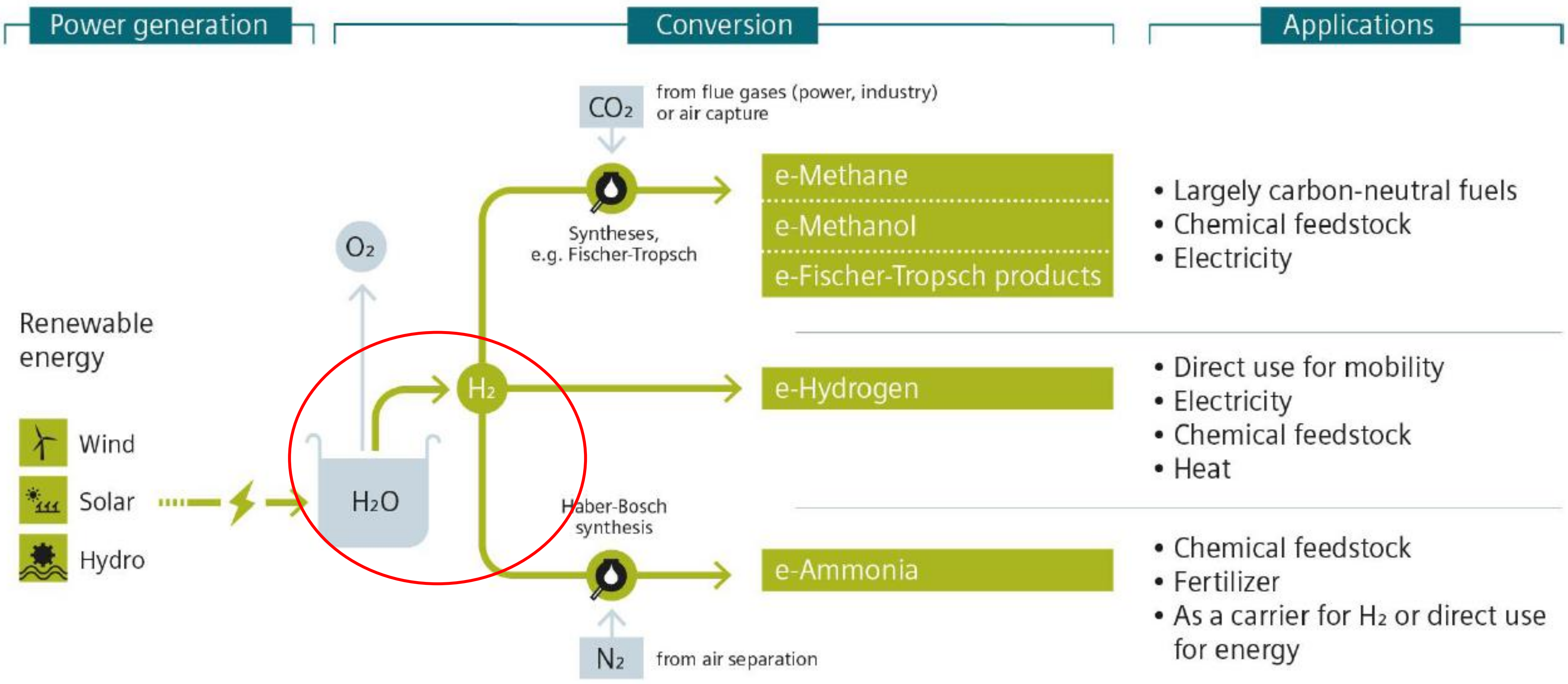
Faroe Islands' energy transition: target



100% renewable electricity in 2030 and no oil use on land, if

- Increased electricity production from renewables
- Increased consumption of electricity in all sectors, particulary Maritime
- Techno-economic viability of PtX
- Resilient energy infrastructure

PtX : indirect electrification based on green H_2



Faroelyzer –Who, What and How

The objective investigate the techno-economic feasibility of using electrolyser-based PtX to support the green transition of Faroe islands

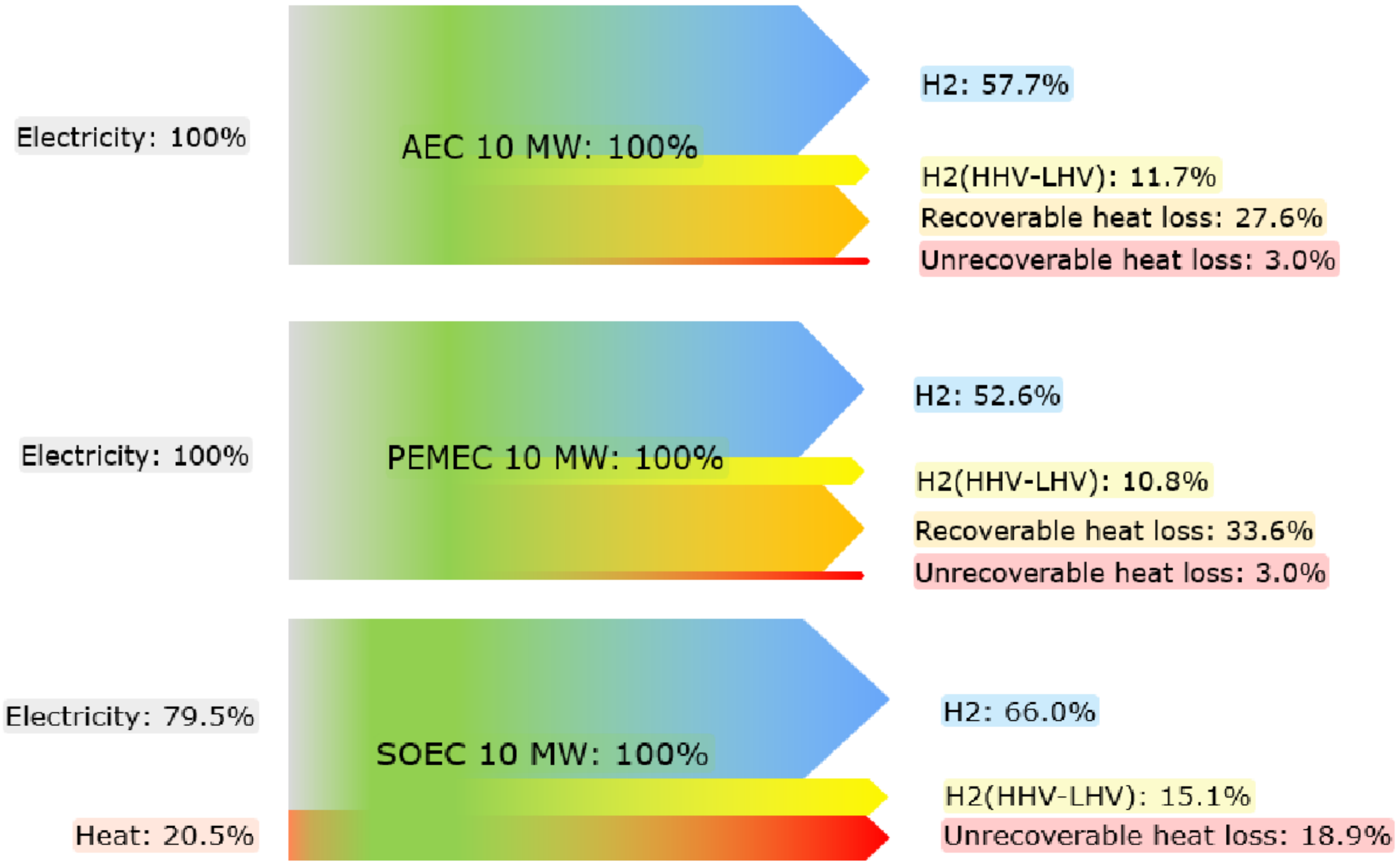
The consortium

– SEV – Common electricity company of Faeroe Islands/SEV
– ORKA Umhvørvisstovan – Faeroese Environment Agency/Orka (us.fo)
– DTU – DTU Wind and Energy Systems/DTU Wind
– NORA – Nordisk Atlantsamarbejde/NORA Projects

The structure

- WP1: Modeling Electrolyzer
- WP2: Electrolyzer integration in Streymoy power grid
- WP3: Electrolyzer’s flexibility potential
- WP4: Economic feasibility and social benefits
- WP5: Management and dissemination

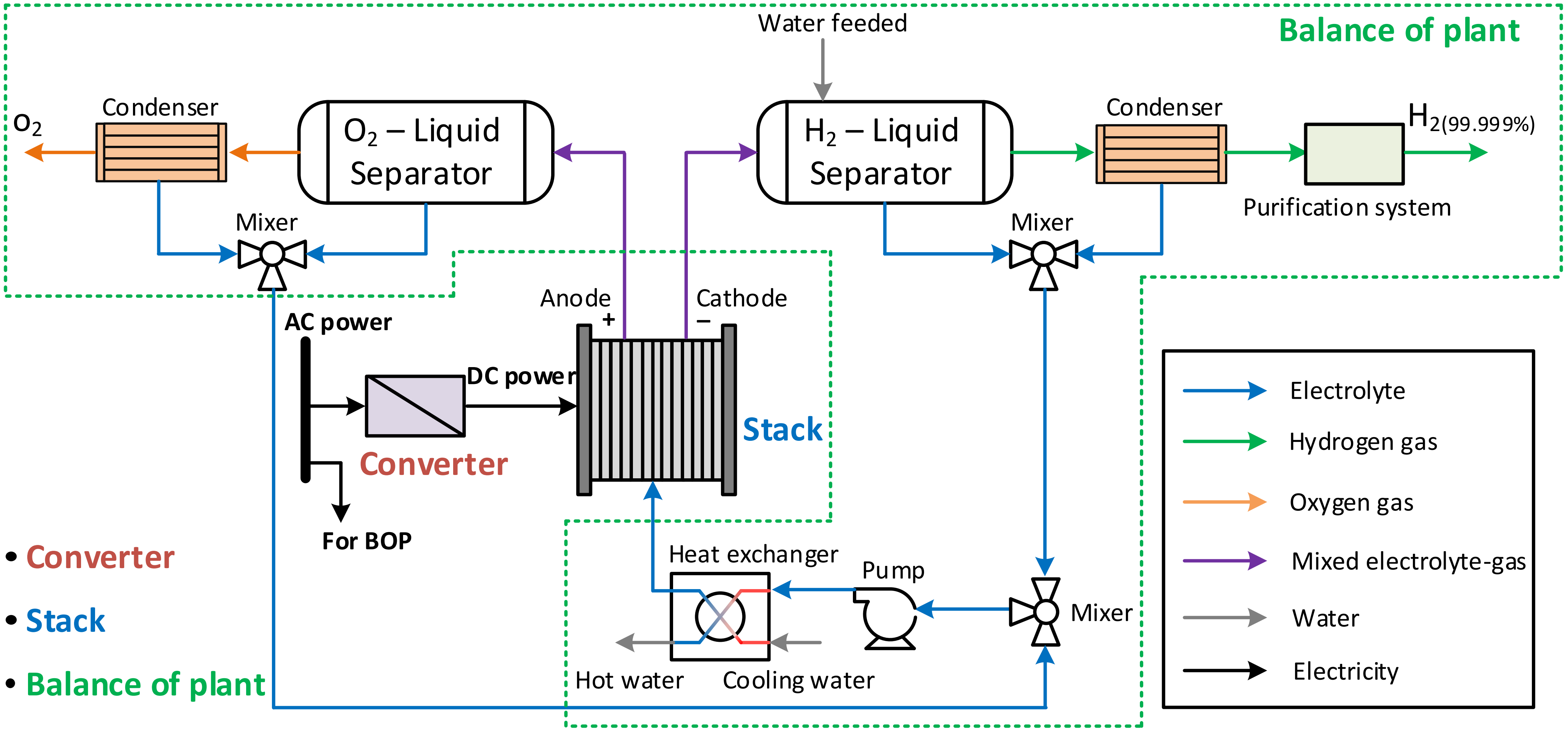
Interim findings – An overview of electrolyzer technologies



CAPEX (€/kW)			
		2020	2025
AEC	10 MW	1900	1400
	100 MW	1200	875
	1 GW	1100	800
PEMEC	10 MW	1900	1425
	100 MW	1300	975
	1 GW	1200	900
SOEC	1 MW	4000	2875
	10 MW	2900	2075
	100 MW	1800	1300

Source: Danish Energy Agency, Technology data for Renewable Fuels, 2024

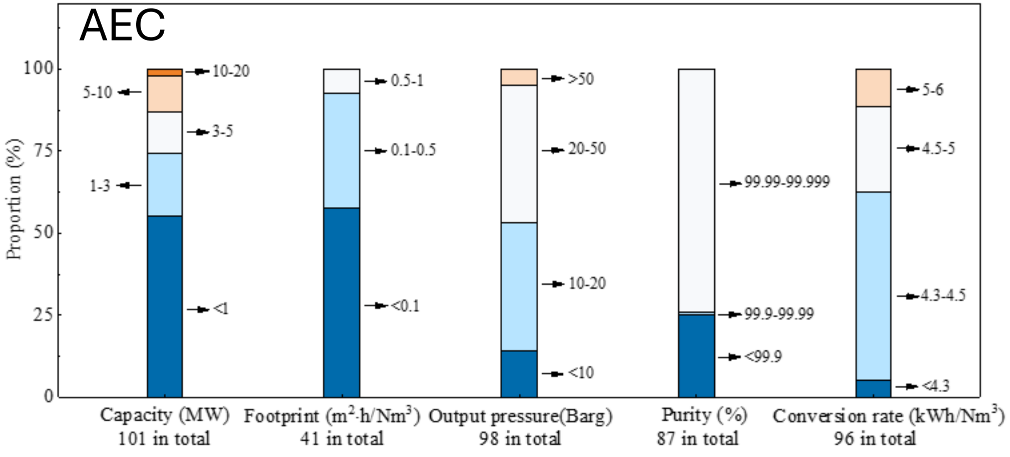
Interim findings – Schematic of an electrolyzer plant

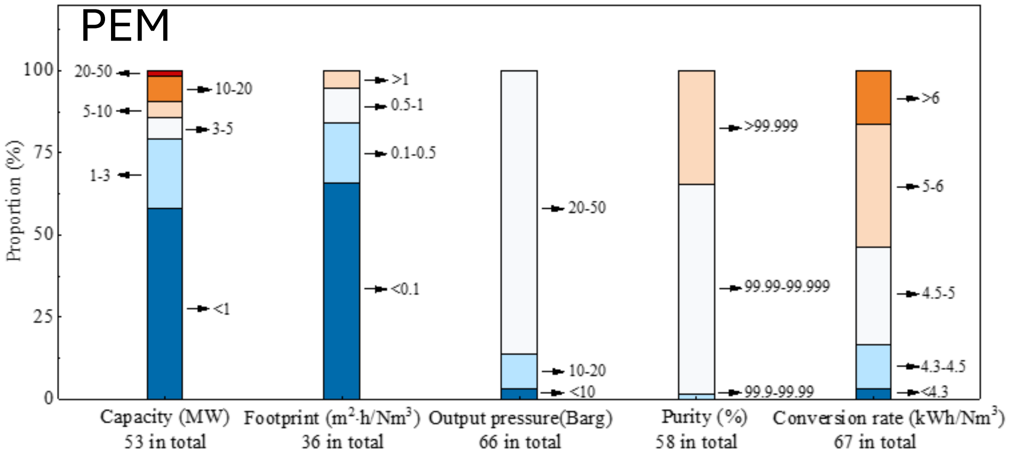


- Converter
- Stack
- Balance of plant

Interim findings – Off-the-shelf Electrolyzer products

186 WE products from 28 suppliers





Source: Jin, X., You, S., Petersen, M., Riofrio, J., Thakur, S., Træholt, C., & Feng, Z. (2024). Exploring commercial water electrolyser systems: a data-based analysis of product characteristics. *Clean Energy*, *8*(1), 126-133.

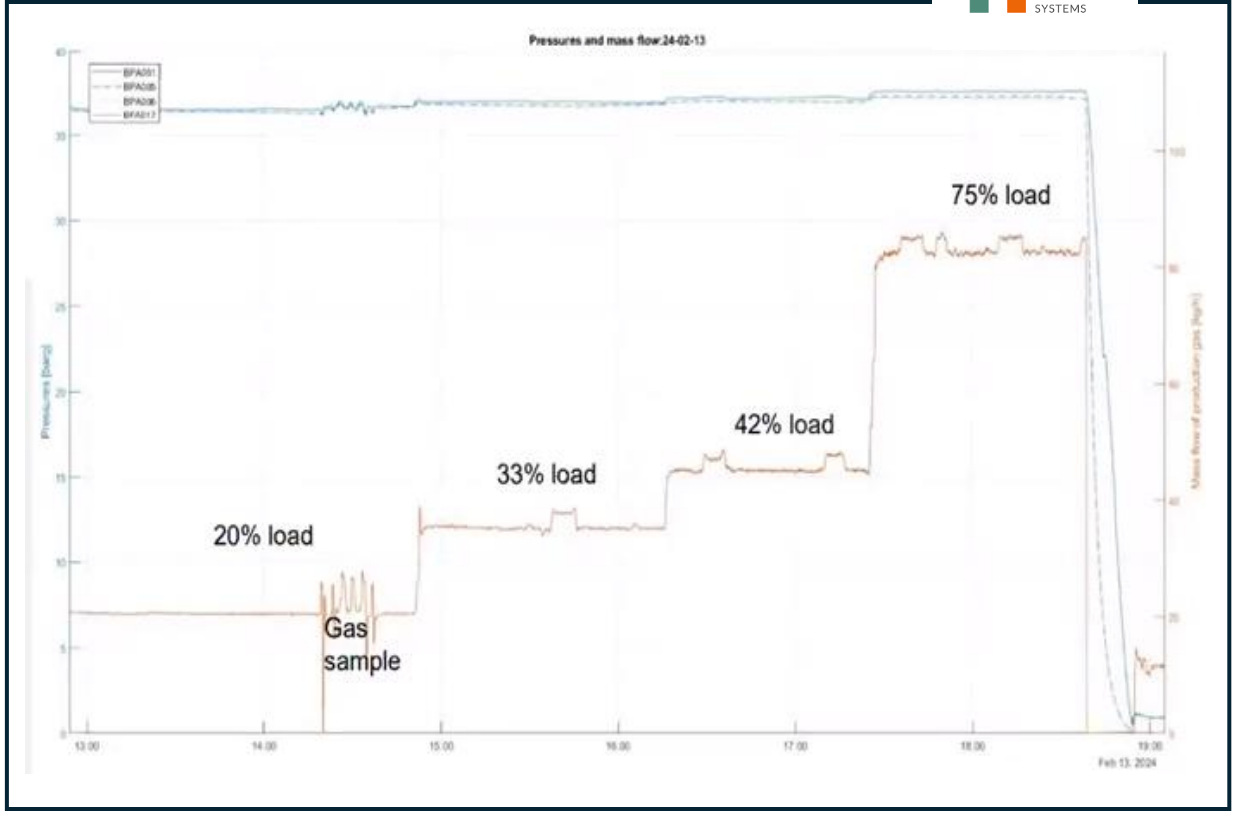
Interim findings – Dynamic performance of electrolyzer

Characteristic	Time horizon	Alkaline	PEM	SOEC
Flexibility				
Load range (relative to nominal load) The overload condition can be kept for a limited amount of time, requires oversized equipment and entails efficiency losses.	Today	10 – 110 %	0 – 160 %	20 – 125 %
	2030	Expected by 2050: 5 – 300 %	Expected for 2050: 5 – 300 %	Expected for 2050: 0 – 200 %
Start-up time (warm, cold)	Today	1–10 minutes	1 second – 5 minutes	< 60 minutes
	2030	Not available	Not available	Not available
Shutdown	Today	1–10 minutes	1 second – 5 minutes	Not available
	2030	Not available	Not available	Not available
Ramp-up / Ramp- down	Today	0.2 – 20 % / second	100 % / second	SOEC have a system response time of few seconds.
	2030	Not available	Not available	Not available
Reactive power	› Electrolysers cannot provide reactive power *per se* as they are a DC loads and limited reactive power is consumed by other equipment in the module. However, electrolysers may be able to provide voltage control through their converters.			

Source: ENTSO-E, Potential of P2H2 technologies to provide system services

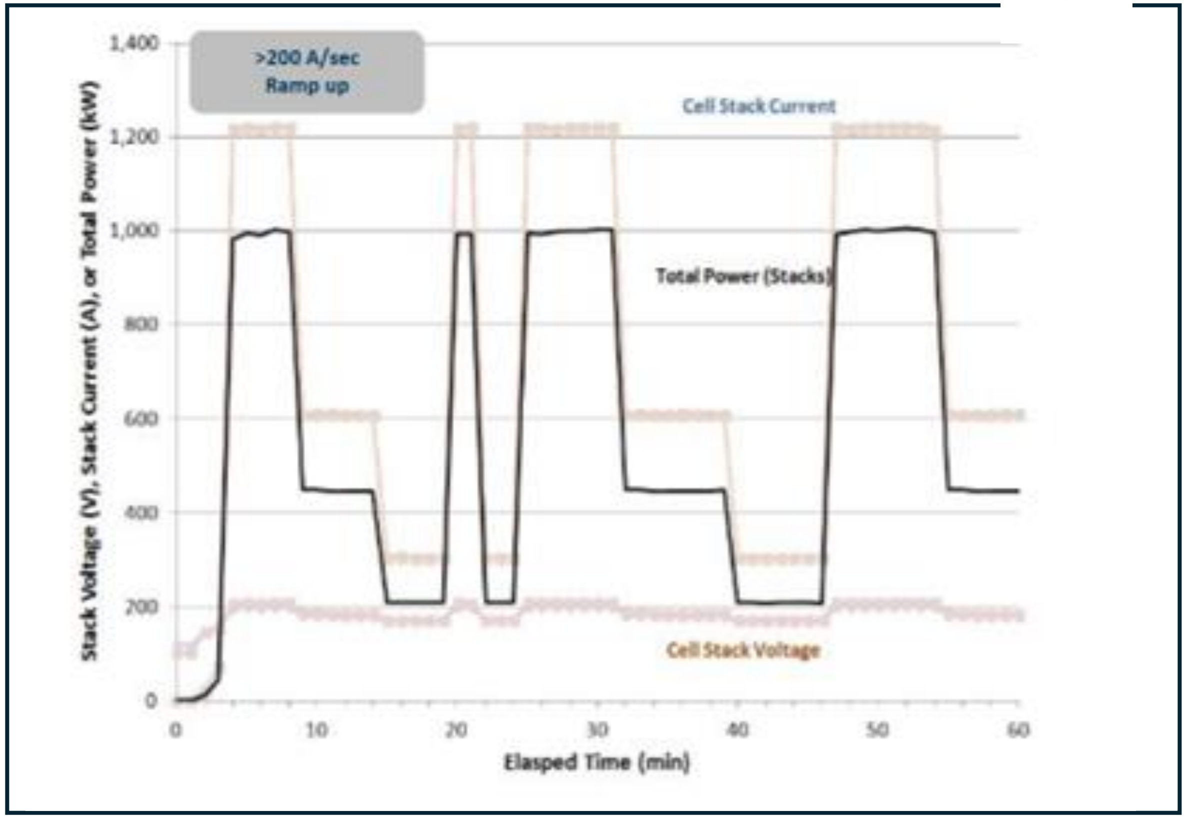
Interim findings – Dynamic performance of electrolyzer

AEC



20%- 100%, 41 sec

PEM



10%- 100%, 6 sec

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Interim findings – Electrolyzer project economy evaluation

Planning ⟷ **Operation**

Portfolio of assets

Wind farm
PV farm
Battery

Land
Electrolyser
H2 Storage & distribution
Water supply
Cables & pipes

Thermal storage & distribution
CO2 Storage
eFuel plants
…

Regulatory factors

Environmental & safety assessment
Biodiversity
…

Social factors

Human rights & acceptance
Jobs & skills
…

Financing

Public vs private
…

Revenue streams

Buy/sell electricity
Buy/sell CO2
Sell (green) H2
Sell (green) O2
Sell (green) heat
Sell (green) methanol
Sell (green) methane
Sell (green) Ammonia
Buy/sell green certificate
Buy/sell ancillary services
…

Operation objectives

Profit maximization
Cost minimization
CO2 minimization
100% Green Products
100% reliable energy supply
…

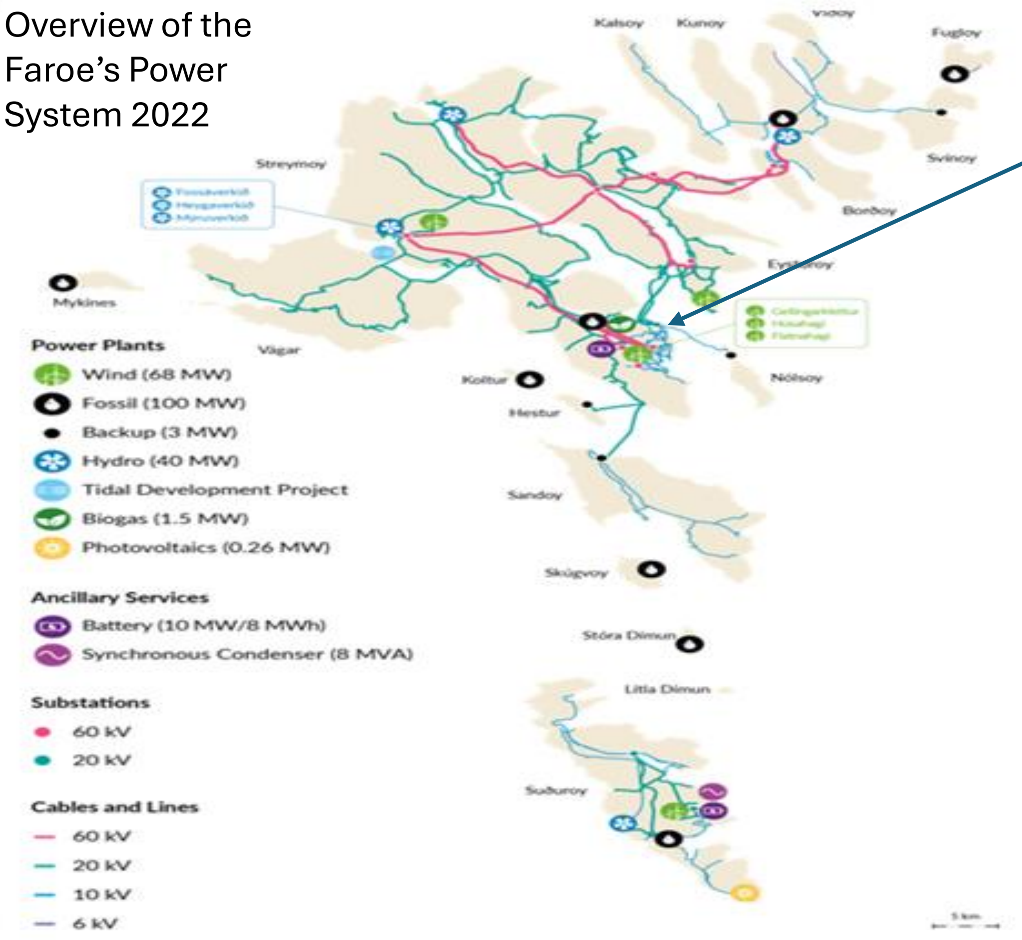
Sensitive factors

- Weather
- Grid-tariff, tax rate
- Incentives
- Pricing strategies for services & products
- Flexibility management?
- …

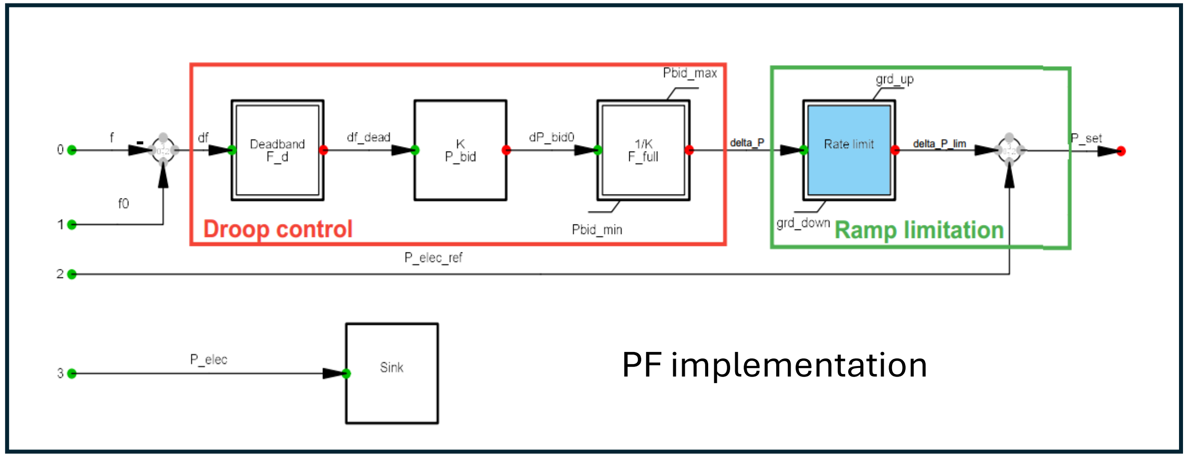
How to develop a robus & profitable business plan (beyond LCOH) under uncertainties?

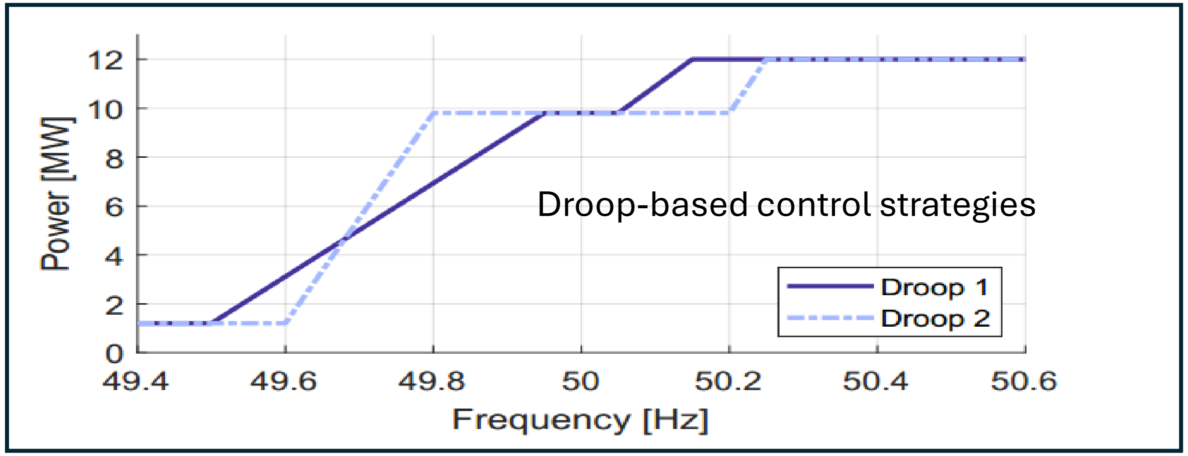
Interim findings – Electrolyzer in Faroe islands' power system

Overview of the Faroe's Power System 2022



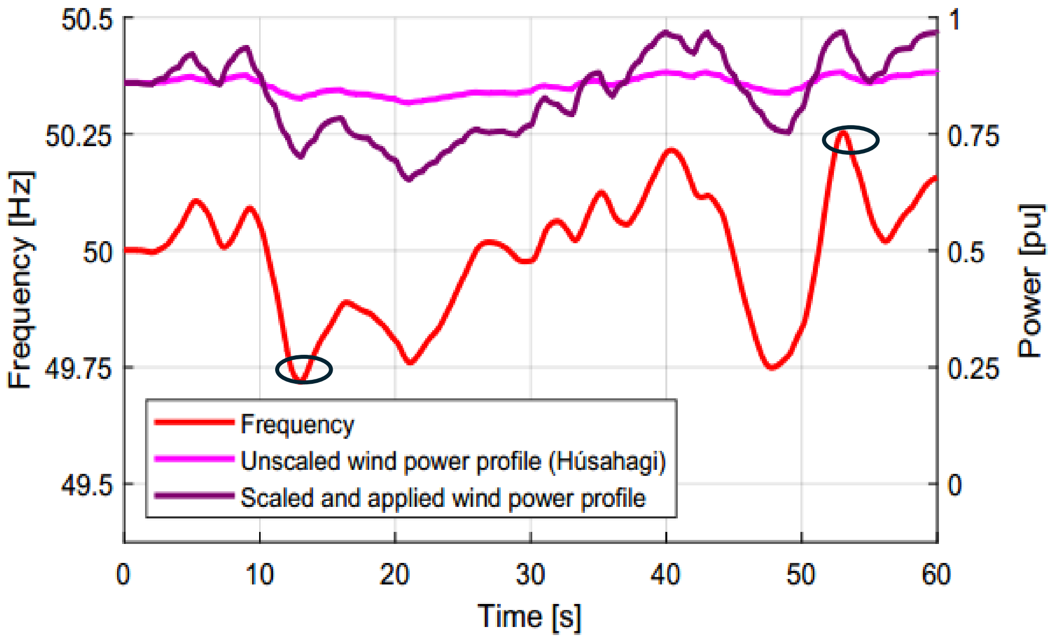
A 12 MW AEL modeled in PowerFactory for both load flow & frequency support studies



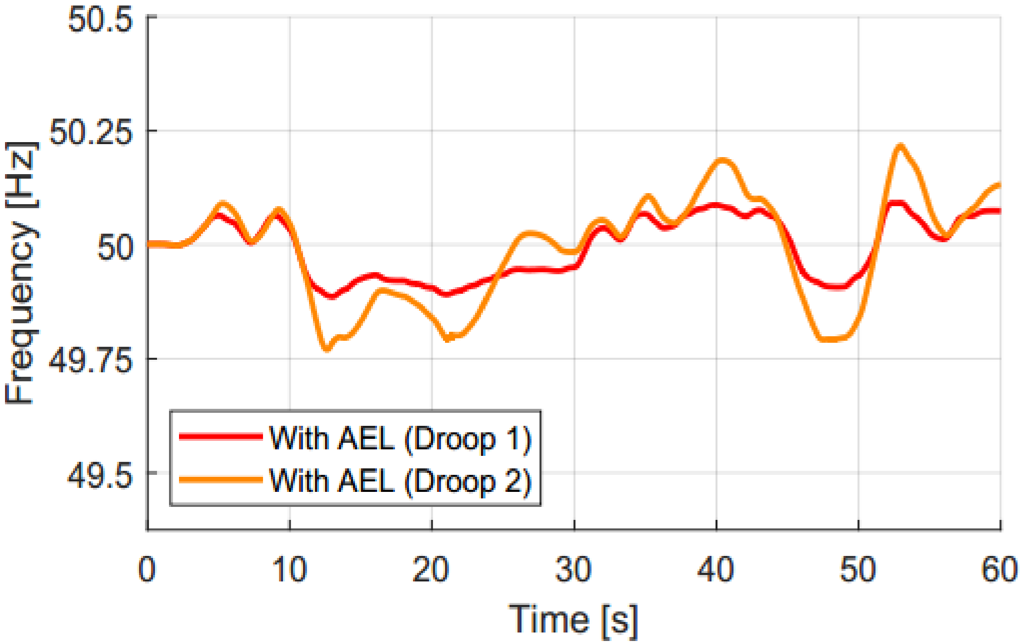


Interim findings – Electrolyzer in Faroe islands' power system

System frequency without the AEL



System frequency with 12MW AEL



Results summary and next step

Results summary

- Generated a comprehensive overview of state-of-the-art electrolyzer technology.
- Developed a relatively generic dynamic model of the electrolyzer for power system analysis.
- Integrating approx. 10MW Electrolyzer in the Faroe Islands' power system is technically feasible, which can also enhance the grid frequency stability if proper control is applied.
- Developed a framework for evaluating the economy of PtX projects.

Next step

- Maintaining awareness of technology development.
- Conducting a more detailed economic viability analysis for selected PtX developers and end-users.
- Converting conceptual studies into demo/commercial applications.

More to read

Student projects

- Arnau Ferrandis Rosello, PtX-based frequency regulation in the Faroe Island's power system, MSc thesis, Feb. 2024
- Asger Nyholm, Analysis and simulation of the integration of PtX into a future wind dominated electrical grid on the Faroe Islands, MSc thesis, Jan. 2024
- Ramon Garcia Gonzalez De Chaves, Integration of Electrolyzers in the Faroe Islands Energy System, MSc thesis, Dec. 2023
- Sverri Jacobsen, Techno-economic assessment of the potential for electrolyzer integration in the Faroe Island energy system, BSc thesis, Dec. 2023
- Gustav von Zernichow Borgberg, Feasibility and techno-economic analysis of selected scenarios of PtX integration on Faroe Islands, BSc thesis, Dec. 2023

Relevant publications

- Petersen, M., Andreae, E., Skov, I. R., Nielsen, F. D., You, S., Cronin, A., & Mortensen, H. B. (2024). Vision of Offshore Energy Hub at Faroe Islands: The Market Equilibrium Impact. *International Journal of Sustainable Energy Planning and Management*, *40*, 115-130.
- Andreae, E., Petersen, M., Skov, I. R., Nielsen, F. D., You, S., & Mortensen, H. B. (2024). The impact of offshore energy hub and hydrogen integration on the Faroe Island's energy system, *Energy Planning and Management* (Accepted)

Thank you

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